US-PAT-NO: 6236751

DOCUMENT-IDENTIFIER: US 6236751 B1

TITLE: Automatic method for determining piecewise linear transformation from an image histogram

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INVENTOR-INFORMATION:

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US-CL-CURRENT: 382/168, 382/169 , 382/172 , 382/274

ABSTRACT:

An image desired to be reproduced is scanned to determine its video pixel grey values. A histogram generator generates a histogram distribution representing a frequency of the grey values. The histogram distribution is analyzed to determine a minimum and maximum input grey values which define input boundaries. A segment point is computed between the input boundaries based on the histogram data. The segment point defines a plurality of input

segments between the input boundaries. A dynamic output range is selected.
Each input segment is mapped to an output segment based on a linear
transformation for the corresponding segment. In this manner, a **tone**
reproduction curve map having a piecewise linear transformation is
automatically generated from the image **histogram** data.

17 Claims, 15 Drawing figures

Exemplary Claim Number: 1

Number of Drawing Sheets: 15

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Abstract Text - ABTX (1):
An image desired to be reproduced is scanned to determine its video pixel
grey values. A histogram generator generates a histogram distribution
representing a frequency of the grey values. The histogram distribution is
analyzed to determine a minimum and maximum input grey values which define
input boundaries. A segment point is computed between the input boundaries
based on the histogram data. The segment point defines a plurality of input
segments between the input boundaries. A dynamic output range is selected.
Each input segment is mapped to an output segment based on a linear
transformation for the corresponding segment. In this manner, a **tone**
reproduction curve map having a piecewise linear

transformation is automatically generated from the image **histogram** data.

Brief Summary Text - BSTX (2):
The present invention is directed to the digital imaging arts. It finds particular application to a system and method of automatically generating a **tone reproduction** curve defining a piecewise linear transformation based on an image **histogram** and will be described with particular reference thereto.

Brief Summary Text - BSTX (23):
In accordance with one aspect of the present invention, a method of generating a real-time tone reproduction curve map is provided. A portion of an image is scanned and input grey values which form the image are determined. A histogram of frequency distributions of the input grey values is generated. A **tone reproduction** curve map is generated which transforms the input grey values to output grey values based on the **histogram** of the input grey values.

Brief Summary Text - BSTX (27):
One advantage of the present invention is that a **tone reproduction** curve is automatically generated based on **histogram** data.

Detailed Description Text - DETX (2):
With reference to FIG. 1, an image or document to be reproduced is scanned 10. Video pixel grey values are determined from

the scanned image and a histogram distribution is generated 15 representing a frequency of each grey value. The histogram is analyzed 20 to determine characteristic features of the scanned image which will affect the manner in which the image grey values will be mapped to output grey values. Analysis of histograms are described, for example, in U.S. Pat. No. 5,751,848 entitled "A System and Method for Generating and Utilizing Histogram Data From a Scanned Image" which is assigned to the present assignee and is incorporated herein by reference. A **tone reproduction** curve is generated automatically from the **histogram** data which maps the input grey values to output grey values.

Detailed Description Text - DETX (17):

With reference to FIG. 6, a **tone reproduction** curve map is illustrated for the image **histogram** of FIG. 5 where the image is adjusted with a piecewise linear **tone reproduction** curve. One can see that the first segment (between grey values 5 and 102) are mapped to a much larger output grey value range (grey values 14 to 197). This improves the shadow detail rendition for this image because the dark grey values are expanded to provide more detail in the shadow region.

Detailed Description Text - DETX (28):

FIG. 10 shows a piecewise linear **tone reproduction** curve generated from the **histogram** data of FIG. 9. This transformation improves the shadow detail

rendition as compared to the "classical" transformation. This is a result of an effective expansion of the dynamic range in the shadow region. To generate the piecewise linear transformation, the histogram of FIG. 9 is analyzed to determine one or more segment points. In this case one segment point is determined which then defines two segments along the input grey values. From the histogram, a black peak is found at input grey level 11. From the black peak, a segment point is computed and selected from about two standard deviations (2 sigma) from the black peak which is at grey level 32.

Detailed Description Text - DETX (33):
With reference to FIG. 12A, a piecewise linear **tone reproduction** curve is shown which is generated for the **histogram** of FIG. 11. In this case, the segment point is selected to be at the first valley grey value 85. Thus, the dynamic input range includes two segments, the first defined between R.sub.min (20) and 85, and the second segment is defined between grey value 85 and 135. The dynamic output range is selected as the entire system range which for an 8 bit system is 0 to 255.

Detailed Description Text - DETX (40):
With reference to FIG. 12B, a piecewise linear **tone reproduction** curve for the **histogram** of FIG. 11 is shown. The difference between the map of FIG. 12B from the map of FIG. 12A is that in FIG. 12B, the transformation selects a

segment point using the 2 sigma value (1/4+L black peak) rather than at a valley point 85. In this case, the 2 sigma point is at grey level 60. The percentage of input pixels between R.sub.min (20) and the segment point 60 is 42.3%. Then, multiplying the dynamic output range 255 times the percentage (255*0.423) gives a value of 108. Thus, a first output segment is defined between 0 and 108 and a second output segment is defined between 108 and 255. The input grey value of 60 at the segment point is mapped to the output segment point value of 108. Similarly as discussed above, the slope for each input segment is computed and the input grey values are mapped to the output grey values in their corresponding segments based on the slope of their segment which gives an overall piecewise linear transformation.

Detailed Description Text - DETX (46):

FIG. 14 illustrates a piecewise linear **tone reproduction** curve map generated from the **histogram** data of FIG. 13 using a dynamic output range of the system (0 to 255). R.sub.min was determined using the 3 percent rule at grey level 11 and the maximum boundary is set at grey level 213 since this image has background values which will be suppressed. The segment point is computed at grey level 39 based on a black peak value of 22 and the 2 sigma point (1/4+L black peak). Two input segments are thus defined for the input grey values. Based on the percentage on pixels on the first segment, the segment point 39 is

mapped to output grey level 136. As previously explained above, the slope of each segment is determined and the input grey values are mapped to the output grey value segments in a piecewise linear transformation. Alternately, the dynamic output range can be selected as a halftone screen range, for example, between output grey levels 14 and 220.

Claims Text - CLTX (4):

generating a **tone reproduction** curve for transforming the input grey values to output grey values based on the **histogram** of the input grey values, the generating of the **tone reproduction** curve further including,

Claims Text - CLTX (37):

automatically generating a **tone reproduction** curve based on the **histogram** data;

Claims Text - CLTX (43):

generating a **tone reproduction** curve for transforming the input grey values to output grey values based on the **histogram** of the input grey values including,